UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 248

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ August 14, 1915

FLEAS

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By

F. C. BISHOPP, Entomological Assistant, Southern Field Crop Insect Investigations

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INTRODUCTION.

Fleas have forced themselves on man's attention for many centuries. All are familiar with these elusive little pests, knowing well their brownish color, peculiar flattened shape, apparent ability to sense the approach of danger, and the proverbial ease with which they escape. Their propensities for annoying man by inflicting bites in rapidly changing situations and for persistently worrying dogs and cats are well known.

However, it is not only in the rôle of annoyers of man or beast that fleas assume importance, for within the last decade the world has come to know fleas in their most important relationship to the welfare of mankind—that of transmitters of disease, and particularly of the dread disease known as plague. Aside from plague, which levies a death toll well into the hundreds of thousands yearly, attention is directed to fleas as important insects on account of their probable

NOTE.—The activities of fleas as carriers of bubonic plague and other diseases, as parasites upon poultry, and as pests to man and other animals are presented in this bulletin. Descriptions, life history, breeding places, hosts, and methods of eradication and control are given.

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connection with the disease of warm climates known as infantile kala-azar. There is also reason to believe that fleas play some part in transmitting leprosy. It has been found that the tapeworm of the dog, which has been known to attack man, is dependent upon some insect in which to develop one of its stages, and the dog flea often serves in this capacity. Another interesting rôle which a certain species of flea has been found to fill, though of no known direct importance to man, is the transmission of a blood parasite of the rat known scientifically as *Trypanosoma lewisi*. One kind of flea which is becoming widely distributed in the Tropics has the peculiar habit of burrowing into the flesh of man, especially around the toes. This species causes severe sores and often permanent crippling. In the United States, aside from their connection with plague transmission, we are concerned most with insects of this group as annoyers of man and animals. In the latter case the pests often become so numerous as to cause more or less loss. This is particularly true of the chicken flea, or "sticktight," which will be discussed in the following pages.

Fleas, as is generally known, are true insects. They have been thought by many entomologists to be closely related to the Diptera, or two-winged flies, but now they are usually considered to constitute a separate order of insects. Their peculiar shape,[1] flattened from side to side, and armature of spines and bristles are closely correlated with their parasitic habits, enabling them to move rapidly between the hairs or feathers of their hosts.

HOSTS OF FLEAS.

Fleas in the adult stage may be said to be parasitic exclusively on warm-blooded animals. A single exception has been recorded—that of one flea which was found attached to a land snake in Australia.

A great many species of birds and most mammals have been found to be infested by these parasites. The group of animals of which the horse, ox, and sheep are representative are probably least subject to attack. It is not the purpose to convey the idea that there are as many kinds of fleas as there are birds and animals. In fact, the number of distinct species of fleas now known is probably not greatly in excess of 400. In general, there are certain birds or animals, spoken of as hosts, upon which these insects prefer to feed.

Some species of fleas appear to have much more restricted host relationships than others; that is, they are found on comparatively fewer animals. In other instances fleas may not be found uncom-

[1] Some knowledge of the structure of a few of our common kinds of fleas may be derived from an examination of the illustrations in the following pages, which, with the exception of figure 1, were drawn by Mr. Harry B. Bradford.

monly on certain hosts, but they are not at home on these and would probably not live long or reproduce if made to feed on them exclusively. This class of hosts usually becomes infested by being closely associated with the true host of the fleas, as, for instance, in case of a rat entering a squirrel burrow or a carnivorous animal devouring a flea-infested rodent and thus getting the insects upon its body. Such hosts are usually spoken of as accidental or temporary. While infestations of this kind are seldom of importance to the host animal from the standpoint of direct injury, they may have a vital influence by transmitting disease and may also have an important bearing on control. As a result of this habit of fleas of clinging to, or temporarily feeding on, hosts which are not necessarily congenial, long lists of species of fleas accredited to a single kind of animal or bird are often found. For instance, more than 20 species of fleas have been taken on common wharf rats.

BITING HABITS.

The sensation produced by the biting of a flea is well known to most persons. The annoyance, however, is partly produced by the movements of the insect and by the mental unrest caused by the knowledge that fleas are present beneath the clothing. The effect of flea bites on man is discussed further on page 16. With very rare exceptions, adult fleas partake of no food other than the blood of warm-blooded animals, and it appears that reproduction never takes place until the fleas have partaken of such blood.

The mouth parts are well adapted to piercing the skins of their hosts and sucking up the blood. The essential piercing organ consists of three slender parts. A groove along the inner sides of two of these, the mandibles, with the closely applied third, forms a channel through which the salivary fluid is forced into the wound and through which the blood is pumped into the body. An idea of the structure of the mouth parts may be gained by referring to figure 1, *e* and *g*.

Most species are easily disturbed when feeding, and this accounts, in part at least, for the frequency with which a single flea may bite.

With the exception of the "sticktight" flea and certain of its relatives, fleas do not remain attached to their hosts for long periods. The amount of time spent off the hosts seems to vary much with the species. Normally the adults feed every day and possibly oftener, but in the case of interrupted meals, as has been mentioned, they may bite a great many times during a day, and some species, such as the cat and dog fleas, probably remain on the host almost continuously, feeding at very frequent intervals. A great many fleas are nocturnal. These

depend largely on finding a host at night, and they tend to keep secluded during the day.

In the case of inoculation of an animal with plague bacilli by a flea it has been observed that there is a relationship between the point of flea attack and the formation of the sweelings, or buboes. In this connection it is interesting to note that certain species show a marked tendency to infest certain portions of the host animal.

LIFE HISTORY.

The fleas pass through four distinct stages of development, viz, the egg, the larva, the pupa or resting stage, and the adult. All of

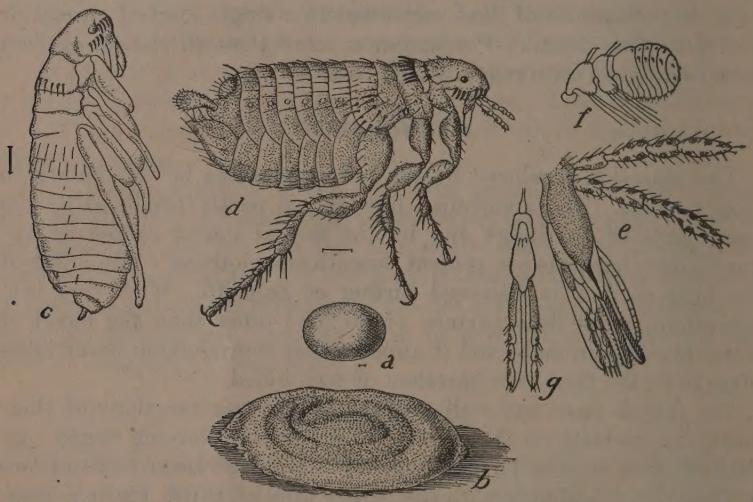

FIG. 1.—The dog flea (*Ctenocephalus canis*): *a*, Egg; *b*, larva in cocoon; *c*, pupa; *d*, adult; *e*, mouth parts of same from side; *f*, antenna; *g*, labium from below. *b*, *c*, *d*, Much enlarged; *a*, *e*, *f*, *g*, more enlarged. (From Howard.)

the different kinds of fleas resemble one another rather closely in these different stages.

THE EGG.

The eggs are ovoid in shape and white or creamy in color, some strongly reminding one of miniature china eggs. Although rather small, they are readily seen with the naked eye, especially if placed on a dark piece of cloth or paper. (Fig. 1, *a*.) They are formed after the female has been feeding on a host for a few days and are usually deposited while the flea is on the host, but are not glued to the hairs or feathers, as is the case with lice and some other insects. The human flea probably deposits most of its eggs while free from the host. The eggs usually fall from the animals in their nests; hence

there is a tendency for the young and, of course, the resulting adults to concentrate in the vicinity of the sleeping places and most frequented haunts of the host. This serves the fleas in three ways: (1) By giving them the protection of the bed of the animal in which to develop; (2) by furnishing food to the young in the form of partly digested blood excreted by the adults while on the host; (3) by keeping these parasites concentrated where they can easily secure access to the host when they become mature. This habit is also important when we attempt to control the fleas and is referred to again under that topic (pp. 25–28).

The number of eggs deposited by a single female and the rate of deposition undoubtedly vary largely with the species, the abundance of food, and climatic conditions. Prof. Bacot, of the Lister Institute, London, in his extensive studies of fleas has conducted a number of experiments bearing on this point. The number of eggs deposited daily is small, but deposition may continue for many weeks. Bacot records 448 eggs as the greatest number observed by him to have been deposited by a single female of the human flea. In some of these experiments he found that the female would continue to deposit eggs for a period of over three months.

THE LARVA.

Within from 2 to 12 days, depending on temperature and moisture conditions, the eggs hatch into minute, whitish, legless, and eyeless maggots. These are not parasitic, but move about actively in the dust and débris in or near the nest of the host. Under favorable conditions the growth of the larvæ is rather rapid. Flea larvæ usually molt twice. The larvæ of the dog flea may molt three times, according to observations made by Mr. Theodore Pergande, of the Bureau of Entomology. The first molt takes place in from 2 to 7 days after hatching, the second from 2 to 6 days later, and the third about 5 days after the second. The shortest larval period observed in these experiments was 7 days. In England Mr. Bacot found that the larval period in the dog flea ranged from 11 to 142 days; in the human flea, from 9 to 102 days; in the European rat flea, from 15 to 114 days; and in the Indian rat flea, from 12 to 84 days. Food, humidity, and temperature are all important factors in influencing the rapidity of development. The larvæ, or maggots, are slender, and each joint is provided with a number of hairs or bristles which assist it in crawling. The head differs slightly in appearance from the other segments and bears some of the usual head appendages with which most insects are supplied. These include short, stout antennæ, or feelers, and a pair of mandibles fitted for biting. The top of the abdomen is provided with two fleshy fingers which aid the larva in its movements,

and a comb of fine hairs. When full grown the maggots are usually less than one-fifth of an inch in length. The larva of a common species is illustrated in figure 3 (p. 14).

The food of the larvæ appears to vary somewhat with the species, since some seem to thrive on a considerable variety of foods, while others are more restricted in their diet. In nearly all species it seems certain that the partially digested blood voided by the adult flea in feeding constitutes an important part of the diet of larvæ, especially when newly hatched. The remainder of the food consists of particles of organic matter, either of animal or vegetable origin, which are found in the cracks of floors, in the nests of the host, or even mingled with the sand near the habitations of the host.

THE COCOON AND PUPA.

When the larvæ have attained full size they spin cocoons of more or less oval shape (fig. 1, *b;* fig. 4). These vary from almost white to brownish, but owing to the particles of sand and dust usually attached the color is often dark. The insect in this stage thus is rendered inconspicuous. In structure the cocoons range from rather light, flimsy silken coverings to very thick tough or even thick brittle encasements. Within the cocoon the larva molts its skin and enters the pupal, or resting, stage (fig. 1, *c*), which somewhat resembles the adult insect. At first the pupa is very pale in color, but it gradually darkens as the time for the appearance of the adult approaches. The length of time spent in the cocoon varies with climatic conditions. At Washington, D. C., Mr. Pergande found that the dog flea would emerge as an adult within from 7 to 9 days after spinning the cocoon. In his experiments in England Mr. Bacot found the period from spinning of cocoons to the emergence of adults to range as follows: European rat flea, from 8 days to over a year; human flea, from 7 to 239 days; dog flea, from 7 to 354 days; and Indian rat flea, from 7 to 182 days.

In these experiments Mr. Bacot found that the period within the cocoon varied markedly with the temperature. This was particularly true with the Indian rat flea, which had its cocoon stage greatly lengthened when the daily mean temperature fell below 65° F. These long resting periods were generally not produced in the case of the human flea until the mean temperature fell to 50° F., and to 40° or 45° F. with the European rat flea. The work of this investigator suggests that the winter is passed in this stage, and that fleas may thus tide over dry hot periods. It is certain that the cocoon offers much protection from adverse weather conditions. The larva may remain quiescent for long periods within the cocoon before actually pupating, and another resting period may occur within the cocoon after the

insect has become adult. Observations made in India and in our own country in the vicinity of San Francisco show that there is no complete cessation of activities in the winter. This is also true as observed in several species by Mr. A. H. Jennings, of the Bureau of Entomology, while in Panama, and the author has observed considerable numbers of fleas on hosts in the Southern States in midwinter. These included the dog flea and the chicken flea, or "stick-tight," as it is colloquially known.

LIFE CYCLE.

The total period from the deposition of the egg to the emergence of the adult, in tests with the dog flea conducted during the summer time at Washington, ranged from 17 to 35 days. The length of the different stages and total life cycle of some of the common species of fleas may be shown best by presenting a table compiled by Mitzmain from the works of various authors, and amplified to include recently published results.

TABLE I.—*Life cycle of fleas in different countries.*

Country and species of flea.	Length of egg stage.	Length of larval stage.	Length of cocoon stage.	Length of complete cycle.
United States:				
Atlantic coast—	*Days.*	*Days.*	*Days.*	*Weeks.*
Dog flea (*Ct. canis*)	2 to 4	8 to 24	5 to 7	2 to 4
Pacific coast—				
Human flea (*P. irritans*)	7 to 9	28 to 32	30 to 34	9 to 11
European rat flea (*C. fasciatus*)	5 to 6	4 to 7	24 to 26	7 to 8
Indian rat flea (*X. cheopis*)	9 to 13	32 to 34	25 to 30	9 to 11
Ground squirrel flea (*C. acutus*)	7 to 8	26 to 28	24 to 27	8 to 9
Europe:				*Days.*
Human flea	4 to 12	8 to 100	6 to 220	19 to 264
Dog flea	8 to 14	12 to 142	10 to 354	35 to 366
European rat flea	5 to 14	12 to 114	3 to 450	20 to 467
Indian rat flea	10 or less	14 to 84	9 to 191	31 to 256
Bird flea (*C. gallinae*)	7 or less	13 to 50	6 to 70+	26 to 127
India:				
Indian rat flea	2	7	7 to 14	21 to 22
Australia:				*Weeks.*
Human flea	6	12	14	4 to 6

LENGTH OF LIFE OF THE ADULT.

Food is the most important single factor in longevity of the flea. Comparatively cool, humid weather greatly lengthens life. Moderately warm, moist weather is more favorable than cool weather for egg laying, but shortens the total life period. Hot, dry weather soon proves fatal to the adult. In connection with this subject reference is made to the work of Mr. Bacot in England, as he has conducted the most complete set of experiments yet published to determine adult longevity. When the temperature registered from 45 to 50° F. and the air was nearly saturated with moisture, this investigator found that specimens of the human flea lived for 125 days, the European rat

flea 95 days and the dog flea 58 days, the Indian rat flea 38 days, and a species of bird or chicken flea (*Ceratophyllus gallinae*) 127 days. These records were made with individuals which received no food whatever. When kept in a box and fed at frequent intervals, he found the human flea to live for more than 513 days. The European rat flea lived 106 days, the dog flea 234 days, the Indian rat flea fed on man 100 days, and the above-mentioned chicken flea 345 days.

In Texas the author has observed the "sticktight," or chicken flea, to live for several weeks attached to a host, but the greatest possible longevity has not been determined.

In experiments conducted in California Mitzmain had specimens of the European rat flea alive for 160 days when fed frequently, the Indian rat flea for 49 days, and the common ground-squirrel flea (*Ceratophyllus acutus*) more than 64 days.

In India and California the longevity with unfed fleas was found to be much shorter than is indicated by the records made in England. Usually the maximum longevity of unfed rat fleas in these warmer climates is but a few days.

Experiments made by Mr. C. Strickland in England, and some conducted by the author in Texas, indicate that the presence of rubbish, dust, or sand, in which the adults may secrete themselves, is an important factor in increasing longevity of unfed fleas. This is especially true during hot, dry weather.

BREEDING PLACES.

In addition to having suitable hosts upon which the adult fleas may feed and thus produce eggs, it is essential that the eggs, the maggots which hatch from them, and the pupæ which finally again produce adults have favorable conditions for development. In houses these conditions are usually found in the cracks of the floors or under matting or carpets. Rat fleas often breed in numbers in granaries, barns, warehouses, and basements, particularly when these are not in constant use or when gunnysacks and rubbish are allowed to accumulate in such places. The immature stages of "sticktight" fleas breed mainly in buildings, such as chicken houses, barns, and sheds which are inhabited by the principal hosts.

Dirt floors in chicken houses or sheds seem to be more favorable than wooden floors for flea development. The young fleas may be found amongst the partially dried excrement, straw, feathers, and other waste in such situations. Fleas have been found also to reproduce in great numbers under corncribs and buildings where dogs sleep or chickens go during the heat of the day. Here the maggots are intermingled with and feed upon the animal and vegetable matter which has accumulated on the soil.

Occasionally fleas, particularly the human flea and dog flea, may breed out of doors. Mr. D. L. Van Dine has recorded an instance in Hawaii where a lawn was infested with the dog flea, and instances are known in the United States of this flea and the human flea breeding in protected situations, as under shrubbery or in the shade of buildings in sand which contains a considerable amount of animal or vegetable matter.

In nearly all cases the breeding places are very closely associated with the haunts or resting places of the host. Instances where adult fleas get upon man well away from such haunts must usually be considered as being the result of the adult fleas having become detached from a host rather than by the fleas having been reared in such situations.

FACTORS INFLUENCING FLEA ABUNDANCE.

Everyone familiar with the flea knows that there is marked seasonal variation in abundance and often distinct variation from year to year. As has been stated, fleas continue to breed throughout the year in California and in parts of our Southern States. This is even more marked in India, Panama, and other tropical countries. The human flea and dog flea are seldom found to worry man during the winter months. This is explained by a falling off in the rapidity of breeding, the comparative inactivity of the adult fleas, and, as Mr. Mitzmain has shown, the tendency for the human flea to remain largely on the lower animals during winter. Throughout the United States the fleas which attack man are most prevalent during the summer months. In India there is a marked decrease in numbers with the oncoming of the hot, dry season. This was particularly noticeable in the case of the European rat flea, which, according to observations of the Indian Plague Commission, began to disappear early in April, and from May 15 to the beginning of November not a single specimen was seen.

The variation from year to year is no doubt principally due to weather conditions. Dr. Howard states that he believes the years of greatest flea abundance are those in which the summer rainfall is above normal. No doubt humid summers, even though the rainfall were not abundant, would produce the same results. These statements are borne out by the effects of dry conditions on the various stages of fleas as observed by several investigators.

Although fleas of one kind or another are to be found all over the United States, there are certain regions where one or more species are especially abundant. In general, in those portions of the country where mild winters and comparatively humid summer atmospheric conditions are the rule fleas are found most prevalent. The amount of rainfall is also a factor in this regional abundance. While

extreme drought is detrimental to reproduction of fleas, excessive rainfall also has a restraining influence. These conditions influencing flea abundance are dependent to some extent on the character of the soil and the presence of hosts and breeding places. Sandy soil is best fitted for flea breeding, as drainage is facilitated and the surface is not so apt to become dried out as on many other soils. In other words, it provides more uniform moisture conditions. It is also probable that sandy soil is of some benefit to the flea by offering more protection to the adult insect.

The local abundance of fleas is, of course, dependent upon factors mentioned in the preceding paragraphs, but in addition the abundance of hosts, their relationship to one another, and the presence of breeding places are of much importance. The abundance of rats in seaports is often responsible for a large flea population, and the continued destruction of the rodents often correspondingly reduces the number of fleas. As has been explained, fleas often feed on several different animals, and when these animals associate they each contribute to the breeding of fleas. An example of this occurs in the instance of the chicken flea, or "sticktight." This flea feeds in great numbers on dogs and cats, and when these animals sleep in and around chicken yards they and their beds are often the source of great numbers of fleas which attack the poultry. Another instance of the effect of the association of hosts and presence of breeding places for fleas may be given. Often untold numbers of fleas may continually infest houses and annoy the inhabitants as a result of hogs, dogs, or other animals being allowed to go beneath the house to make their beds.

THE JUMPING OF FLEAS AND OTHER MEANS OF SPREAD.

The question of the distance a flea can jump, especially in a vertical direction, is important in considering isolation of man or animals from them. The jumping powers of fleas are exaggerated in the minds of most people. The human flea is probably the strongest jumper. Mitzmain, working in California, found the maximum horizontal distance this species could jump was 13 inches. He found a few specimens could jump to a height of 7¾ inches. Five inches has been recorded as the maximum horizontal jump of the Indian rat flea by the Indian Plague Commission, and in experiments conducted by Mitzmain 3⅛ inches was the greatest height to which this species could jump. In other tests investigators found that the European rat flea and common ground-squirrel flea (*Ceratophyllus acutus*) could jump slightly less than 3½ inches in a vertical direction. Observations of the writer on the sticktight flea indicate that its jumping power is almost nil. The legs of this species are comparatively

small, not being developed for jumping like those of the human flea and other species.

Nearly all fleas have more or less difficulty in crawling on smooth surfaces or on clothing, yet in time they are capable of making considerable progress on clothing, either in a vertical or a horizontal direction.

The movements of the fleas themselves are of little direct importance in spreading the species. Their jumping powers, however, aid them in finding hosts and securing attachment thereto, and upon the hosts, whether normal or temporary, they may be carried considerable distances. The species are further disseminated by the scattering of eggs as an infested host goes from one place to another and by the dislodgment of the females from the host. Since the fleas leave a dead animal, in this way adults are scattered, and in some instances they may be infected with the disease from which the host died. The greatest spread of fleas is no doubt brought about through the transportation of infested animals from one place to another through the agency of man. In this way rat fleas may be carried between ports in all quarters of the globe on rat-infested ships. Chicken fleas and dog and cat fleas may also be shipped long distances on infested hosts. It is also possible to spread fleas in merchandise, either in the adult or immature stages. Consideration of these points is of much importance in preventing the spread of plague from one locality to others.

FLEAS AS CARRIERS OF DISEASE.

BUBONIC PLAGUE.

Although the dread disease of man known as bubonic plague has occurred in the United States, the most important outbreak being in San Francisco during the last few years, fortunately it was restricted closely to the portions of the country where it was introduced.

The earliest records of the disease connect the outbreaks in the human family with death among rats. At the present time the disease is considered to be essentially a disease of rats. Man and other animals become infected through the agency of fleas as a result of these epizootics among rats.

The malady has a history dating far back in Biblical times. Probably the worst outbreak known began in the eleventh century and culminated in the fourteenth. During this period practically the entire Eastern Hemisphere was swept, and the number of deaths due to the "black death," as it was known in parts of Europe, was appalling. Within the last 18 years this malady has caused the death of over 7,000,000 in various parts of the world. During the last decade the disease has broken out in various parts of Africa, Europe, Australia, Japan, South America, West Indies, and in the United States.

As a result of international regulations, including quarantines, and owing to the work of the Public Health Service, the disease has not assumed serious proportions in this country. Although the malady has persisted for some time among rats and ground squirrels in and near San Francisco, very few human cases have developed, and the malady has been entirely stamped out in that vicinity. The occurrence of plague in New Orleans during 1914 caused some excitement, but by prompt action by the State and Federal authorities the outbreak has been limited to that city and the number of human cases has been small. In India, China, and a number of other countries the disease is still present in epidemic form, despite the work of the Indian Plague Commission and other organizations for the furtherance of control work. Marked progress is being made, however, and the ultimate stamping out of the pestilence may be expected.

As has been stated, the flea is the medium by which the disease is spread from rats and ground squirrels to man. These insects also act as carriers from rat to rat. That the flea is responsible for the transmission of plague has been determined within the last two decades as a result of studies conducted by a number of investigators in various parts of the world. The importance of an accurate knowledge of these insects in this connection is apparent to all. It has been determined by the Plague Commission of India and other investigators that several species of fleas may serve as vectors of plague. Those which are commonly found on rats and ground squirrels and which may carry plague under certain conditions include the following species:

The Indian rat flea (*Xenopsylla cheopis* Roth.).

The European rat flea (*Ceratophyllus fasciatus* Bosc.).

The human flea (*Pulex irritans* L.).

The European mouse flea (*Leptopsylla musculi* Dugès).

The dog flea (*Ctenocephalus canis* Curtis).

The squirrel fleas (*Hoplopsyllus anomalus* Baker and *Ceratophyllus acutus* Baker).

The cat flea (*Ctenocephalus felis* Bouché).

The rat fleas *Ceratophyllus anisus* Roth. and *Pygiopsylla ahalae* Roth.

The former of the last two mentioned occurs in the East Indies, where it has been shown to be capable of carrying plague, and the latter takes the place of the European rat flea in China and Japan. All of these species, with the exception of the last two named, are found in the United States.

The very severe outbreak of plague in Manchuria a few years ago is thought by many to have started among trappers of the "tarbagan," or groundhog, as a result of having been bitten by the flea, *Ceratophyllus silantiewi* Wagner, which is abundant on this animal.

The Indian rat flea has been found to be by far the most important in plague transmission in India, and this species is now widely distributed throughout the Tropics and in seaports which have direct trade with the Orient. At the present time this species is abundant in parts of the seaport cities on the Pacific and Gulf coasts of the United States. Away from the water front its place as a rat parasite is largely taken by the European rat flea (*C. fasciatus* Bosc.) and the mouse flea (*Leptopsylla musculi* Dugès). The

FIG. 2.—The European rat flea (*Ceratophyllus fasciatus*) : Adult female. Greatly enlarged. (Original.)

human flea is common in many parts of the country, and the squirrel fleas mentioned are abundant on ground squirrels (*Citellus beecheyi*) in the western part of the United States. All of these fleas have been found to bite man and will feed on rats. The adult European rat flea is illustrated in figure 2, the larva of this species in figure 3, and the cocoon in figure 4.

As has been stated, plague always occurs among the rodent population before any number of cases develop in man. The rats in a plague-free community usually receive their initial infection from a diseased rat which has been imported from some plague center. This,

together with the favorable conditions as regards rats and fleas in seaports, accounts for the fact that the disease usually first breaks out in such places. The pestilence, when once introduced, is carried rapidly from rat to rat by the fleas. This spread is increased by the fact that most of the fleas leave the rats as they die and pass to others. It is these fleas, set free by the death of their plague-stricken hosts, which form the chief menace to man.

The method by which fleas convey plague germs has received considerable attention, and various theories have been advanced from time to time in an effort to explain the mechanism of transmission. It appears that the two most important methods are by contamination of the skin of man or other host by excrement voided by the infected fleas while feeding and the subsequent rubbing or scratching in of the germ-laden material and by the injection of the disease organism into the wound made by the flea at the time of feeding. Researches made by Mr. A. W. Bacot, of the Lister Institute, have proven this last method to be an important one. He showed that the entrance to the stomach of some of the fleas becomes plugged by a growth of the plague germs. This ultimately prevents the passage of food backward into the stomach, but does not prevent the flea from sucking up small quantities of blood, some of which is forced back into the wound after becoming laden with the disease organism.

FIG. 3.—The European rat flea: Larva. Greatly enlarged. (Original.)

FIG. 4.—The European rat flea: Cocoon. Greatly enlarged. Note the particles of sawdust and dirt adhering to the surface. (Original.)

Close trade communication between the nations of the world gives increased channels for the dissemination of various pests and diseases as well as opportunities for the furtherance of knowledge and the exchange of trade commodities. The colonization of new lands in the Tropics, the opening of a great artery of trade intimately connecting many of our ports with the commerce of the world, the immigration brought about by the present European strife—these, when considered together with the fact that plague is now present in many quarters of the globe, should impress all with the importance of exercising great care to exclude the disease from our shores. Knowing that this pestilence spreads among people only as a result

of the dissemination of the disease among rodents by fleas, the importance of rodent destruction and of flea control, which go hand in hand, needs no further emphasis. It is not sufficient for the farmer, merchant, and others concerned to depend upon the quarantine authorities to keep plague from being introduced. They must aid the quarantine officers by waging war on the rats and ground squirrels and by preventing flea breeding.

Turning from the rat as a sanitary menace, ample argument is found for its destruction on account of its importance as a destroyer of various agricultural and food products. It has been conservatively estimated that there are in the United States at least as many rats as people. It has also been computed that the annual upkeep of each animal amounts to between $1 and $2. From these figures it is seen that the annual loss due to these rodents must be upward of $100,000,000.

The control of rats is difficult but not impossible, the principal methods being trapping, poisoning, destruction by natural enemies, and, probably most important of all, rat proofing. The question of the relation of rats to man has been treated in publications of the Public Health Service and of the Bureau of Biological Survey.[1]

This work of rodent destruction, clearing up of breeding places, and rat proofing of buildings has an important beneficial influence on flea conditions. Some of the hosts of the fleas are removed and the breeding places of the insect destroyed to some extent. However, these practices can not be depended upon to control all of the species of fleas important as pests.

KALA-AZAR.

One form of another important group of diseases of the Tropics, known as kala-azar, an infectious fever, is considered by some authorities to be carried by the dog flea and human flea. The particular form of the malady in question occurs in the Mediterranean region. On these shores dogs and children are attacked by a similar disease. Investigators have produced strong evidence that the disease is identical in the two hosts and that fleas are responsible for its transference from the one to the other.[2]

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[1] Lantz, D. E. How to destroy rats. U. S. Dept. Agr., Farmers' Bul. 369, 20 p., 5 fig., 1909.

[2] Fleas and dogs.—In Europe with regard to infantile kala-azar, the dog has been found to harbor Leishmania, and a fairly presumptive case has been made out as to the part this animal plays as an intermediary host, the dog flea being the actual transmitter. Donovan believes, however, that the evidence adduced so far is not in all respects convincing. The occurrence of a natural flagellate of the flea has evidently not been taken into sufficient account. (Donovan, Lieut. Col. C. Kala-azar, its distribution and probable modes of infection. *In* Jour. Trop. Med. London, v. 16, no. 16, p. 253–255, 1913.)

LEPROSY AND OTHER DISEASES.

Leprosy is another serious malady with which, according to some investigators, fleas may be connected. This relationship has not been established, but it is well for us to consider all such possibilities. The part fleas play in the life economy of certain tapeworms has been mentioned, as has also their connection with certain rat-infesting organisms. Various other low forms of animal life, many of which are no doubt parasites of the flea itself, have been found in the organs of that insect in different stages of its life.

FLEAS AS PARASITES OF MAN AND ANIMALS.

As has been shown, a considerable number of the common fleas of this country may be concerned in the transmission of certain diseases if these are once introduced. Several species are, however, of much importance to man aside from their possible connection with disease. It is with the fleas which annoy man or attack poultry or dogs that the people in general are most concerned.

The effect of the bites of fleas varies much with the individual attacked and also with the identity of the flea concerned. The direct effect of these bites, aside from disease transmission, has received little attention. Usually in man pronounced red, itching papules, in some cases with whitish centers, occur at the site of the puncture. Some more susceptible individuals show marked irritation, swelling, and even ulceration following attack. The papules may persist for several days, but usually disappear within a few hours. The irritation is probably induced largely by the injection of the salivary secretion into the wound. This injection causes a rush of blood to the spot, which facilitates the feeding of the insect and in turn causes irritation in the host. The question of acquiring immunity to annoyance by fleas is an interesting one. Many cases have been reported wherein individuals have enjoyed marked immunity to the effect of fleabites and comparative freedom from annoyance after being exposed to the fleas of California. The species concerned in these instances was without doubt the human flea. Others report a similar diminution in the annoyance caused by the dog flea. A brief discussion follows of the more important species from the standpoint of annoyance to man and domestic animals.

THE HUMAN FLEA.

The species of flea known scientifically as *Pulex irritans* L. has long been considered the human flea. It is to be found in practically every portion of the earth frequented by man. It is quite distinct from other fleas in structure (figs. 5 and 6), and is largely dependent

upon man as a host, although in Europe it seems to thrive on the badger, while in the United States it is commonly taken on the skunk. It has also been taken on hogs, rats, and various other animals, but these are usually but temporary hosts and insufficient to maintain the species.

On the Pacific coast the species is responsible for practically all annoyance to man due to this group of parasites. It has been found to be the one concerned in nearly all cases of house infestation in that section. In the Southern and Eastern States, as will be pointed

FIG. 5.—The human flea (*Pulex irritans*): Adult female. Greatly enlarged. (Original.)

out later, the dog flea is more important as a pest to man than the human flea. Our main interest in the human flea is on account of its annoyance to man, as it is not as yet known to play any part in disease dissemination in this country. Nevertheless, the possibility of its being an occasional carrier of plague and also that it may transmit the infectious fever kala-azar of the Mediterranean region should not be lost to sight.

Curiously enough, the human flea appears to have adapted itself to the varied conditions under which man lives. It breeds freely in all situations occupied by man, and in the immature stages is one of the most hardy species known to science. The biology of this species,

as compared with others, has been briefly outlined in the preceding pages, and control measures, applicable to this and most other species, are discussed in the following pages.

THE DOG FLEA.

The dog is undoubtedly the normal host for the flea which is known scientifically as *Ctenocephalus canis* Curtis (fig. 1); nevertheless the insect is not averse to partaking of a meal of blood from man or a cat, especially when its normal host is not at hand. Like the

FIG. 6.—The human flea: Adult male. Greatly enlarged. Note the difference in the shape of the abdomen of the male as compared with the female (fig. 5). (Original.)

human flea, this species has a wide distribution throughout the world; in fact, it is generally considered the most widely distributed species of flea.

As an annoyer of man the dog flea ranks next to the human flea. In the eastern United States, as has been pointed out by Dr. Howard, instead of the human flea this is the species usually reported as infesting houses. In some instances reported to the Bureau of Entomology houses have been rendered almost uninhabitable by this aggressive insect. The most severe infestations, as reported by Dr. Howard, have occurred in cases where dwellings have been closed up during summer, and when opened upon returning the occupants were greeted

by hundreds of fleas. Rainy summers are most favorable for such development, supplying enough dampness to the dust, which is left undisturbed in the cracks, successfully to mature the eggs and fleas which are present. The original stock of fleas must, of course, be derived from pet dogs or cats which occupied the house before it was vacated, or, as often happens, dogs may take up their abode under or around the house in the absence of the occupants. Thus great numbers of eggs are dropped, and breeding proceeds undisturbed. It should be noted that the stray dogs and cats which are likely to find homes in unoccupied buildings are often heavily infested with fleas, usually much more so than animals with a home and having more or less attention paid to them.

In this country the dog flea is not known to be responsible for the transmission of any disease, but it holds a position of distinct importance as a household pest. Its importance as an enemy of the dog and cat is not small. Breeders of fine cats and dogs often have considerable trouble in ridding their stock of fleas, and hunting and other dogs, particularly in the South, are kept in poor condition as a result of gross infestation. The fact that one stage of a tapeworm which commonly infests dogs and occasionally children in this country lives within the dog flea still further increases the importance of this parasite.

THE STICKTIGHT FLEA.[1]

One need but visit a few poultry farms or inquire of almost any farmer with his little flock of chickens for home use in the southern and southwestern portions of the United States to get some idea of the importance of the so-called "sticktight flea" (*Echidnophaga gallinacea* Westw.). Other colloquial names which are applied to the insect are "third-party flea," "chicken flea," or "black flea." The name chicken flea is applied because of the frequency with which chickens are infested. Black flea is a name applied less frequently and is given on account of the very dark color of the adult fleas. The name "sticktight" is used most generally in the South, and it is aptly applied. The species differs markedly in feeding habits from most of our common species. It seldom hops about, biting here and there, as in the case of the dog and human fleas, but when a suitable host is found it settles down, deeply inserting the mouth parts, and remains

[1] In a publication just issued (Herrick, Glenn W. Some external parasites of poultry with special reference to Mallophaga, with directions for their control. Cornell Univ. Agr. Expt. Sta. Bul. 359, p. 230–268, fig. 95–116, Apr., 1915.), the point is brought out that the European hen flea, *Ceratophyllus gallinae,* was received from Abington, Mass., and Barker, N. Y. In each of these cases the flea was collected in hen houses, and the collectors state that the insect was very annoying, especially to human beings. Prof. Herrick calls attention to the fact that Mr. C. F. Baker reports the collection of a single specimen of this flea at Ames, Iowa, and refers to a note by Dr. M. Francis to the effect that the species occurred at Bryan, Tex. It is possible that in time this insect may become a pest of some importance to poultry in the United States.

for days or weeks. Its hold on the host is difficult to loosen. Another marked tendency is for the adults to attach to hosts in dense masses. A chicken is frequently seen with a large portion of her head closely set with these fleas, making it appear almost black. These dense masses are often seen on the ears of dogs or cats, particularly at the very edge of the ear. The characteristic appearance of an infested chicken's head is shown in figure 7.

The hosts of this flea are, unfortunately, rather numerous. As has been stated, chickens are commonly attacked, and it is on this host that the species assumes its greatest importance as a pest. In the investigations by the author it has been found in abundance on dogs, cats, tame rabbits, ducks, and turkeys. It is not infrequently found on people who go about infested poultry yards, and children, crawling beneath houses where infested animals go, are often bitten. The species does not attack man very freely. It is seldom found in houses except on rare occasions, when a few specimens may be brought in on the clothing. In one instance in western Texas a burrowing owl was killed and found to be heavily infested about the head with this flea. In another instance in the same region a wood rat, or pear rat, as it is commonly known there, was found to harbor a number of sticktight fleas. Several years ago Prof. J. C. Hartsell, of Orangeburg, S. C., reported to the Bureau of Entomology instances where horses were heavily infested with these fleas on the lower portions of the legs. Others have recorded it from cattle, and a number of specimens have been taken on rats and other hosts in different parts of the world.

FIG. 7.—Head of rooster infested with the sticktight flea (*Echidnophaga gallinacea*). Somewhat reduced. (Original.)

The species was originally described from India, but it now appears to be widely distributed throughout the Tropics and the warm temperate regions. In the United States it is seldom seen north of the Southern and Southwestern States. Reports indicate that the species is spreading; at any rate, it would seem that the South is becoming more generally and completely infested.

No disease has been found to be carried by the sticktight flea, but its importance as a parasite places it among the principal insect enemies of poultry in the South. The principal direct loss is due to the attack of the fleas on young poultry, as high as 85 per cent of young

chickens hatched having been reported lost on account of the fleas. In many cases young chickens, turkeys, and ducks have a combined infestation of sticktight fleas and biting lice, and each contributes to the worriment and weakening of the fowls. A few cases of death observed among grown chickens apparently have been due to fleas. In these instances not only the heads and necks of the chickens were largely covered but numerous patches thickly set with fleas existed under the wings and on the breast. The fowls heavily attacked become droopy, lose appetite, and fall off in weight. Mild infestations on grown fowls cause no marked injury, but no doubt egg laying is influenced to some extent, and certainly infested fowls are unsightly.

The fleas are present on hosts throughout the year, but they are usually more numerous in the summer and fall. The species appears to thrive best in ill-kept chicken houses, where chickens roost under buildings, and where dogs and cats have their beds closely associated with the poultry. This point will be discussed further under the general topic of control. The eggs are dropped by the females while attached to the host. These fall beneath the roost, hatch, and the young larvæ feed on the excrement of the parent fleas and on other animal and vegetable refuse.

FIG. 8.—The sticktight flea: Adult female. Much enlarged. (Original.)

The species is one of the smallest fleas in this country and very dark brown in color. The body is comparatively short and deep, and the legs are slender, but the mouth parts are large and strong. The male is usually slightly smaller than the female (fig. 8), almost black, and is more frequently seen moving about on the host than the female.

THE CHIGOE FLEA.

The flea commonly known as the chigoe or "jigger" (*Dermatophilus penetrans* L.)[1] is related to the sticktight flea, but has different

[1] This should not be confused with the "chigger" or harvest mite, which is the larval form of Trombidium.

habits. Instead of remaining attached to the surface of the host, the female, after being fertilized, burrows into the flesh until it may become completely embedded. When it first reaches a host it feeds much as does the sticktight flea, the burrowing tendency becoming evident only when the eggs are developing. A number of hosts are attacked, particularly the hog. Cats, dogs, cattle, sheep, horses, and even birds are attacked, but attention has been directed to the species largely through its infestation of man. Its attack is usually confined to the feet of the host, and in man particularly to the toes. The females may enter between the toes or under the toenails, and severe inflammation often follows, with the formation of ulcers, frequently resulting in permanent crippling. While in the host the eggs develop within the female and the abdomen becomes greatly distended, often attaining the size of a small pea. The legs of this species are not large, and when this distention takes place they, as well as the head, become very inconspicuous.

The eggs are deposited while the flea is attached and may drop from the wound or pass out with the detached flea. So far as known the rest of the life history is similar to that of other species.

The chigoe is not known to be established in the United States, although it has been reported on a few occasions from Florida. It is a troublesome pest in the West Indies, in parts of Mexico, and in much of South America. It is native to the American Tropics, but about 1872 it was introduced into western Africa. The African conditions were favorable for the pest, and it soon became established in east Africa and Madagascar and spread to the interior of the continent. It was introduced more recently into India, but it appears to have spread very slowly there.

Conditions in Florida and southern Texas would seem to be favorable for this insect, and if care is not exercised it may be introduced and become established in this country.

NATURAL CONTROL.

As has been stated, hot, dry weather is detrimental to flea development. Likewise excessive moisture in a breeding place destroys the immature stages. The direct rays of the sun in summer are important in reducing the length of life of the adult flea and destroying the immature stages. It is possible to take advantage of these natural factors to a considerable extent in fighting the pest, as is brought out later.

Little is known of the natural enemies of fleas. Certain short-winged beetles termed staphylinids are known to prey upon the adult fleas, and certain species of mites have commonly been found upon them. In Texas ants have been observed to prey upon the eggs and

larvæ. No doubt a number of insect enemies of the immature stages exist, but they are probably less important in control than climatic factors. Chickens seem to be capable under some conditions of interfering with the development of the immature stages of fleas by scratching their breeding place about, and no doubt they eat some of the fleas in their various stages.

ARTIFICIAL CONTROL.

In order to prevent an outbreak of fleas, and more especially to control an infestation which has become established in or about a house, it is usually necessary and always advisable to combine two or more of the measures discussed below in order promptly to control the situation.

DESTRUCTION OF FLEAS ON HOSTS.

In nearly all cases of flea infestation by either the human flea or the dog flea in houses or by the sticktight flea in poultry yards the destruction of the fleas on the hosts is important. Dogs and cats are the animals of particular importance in this connection, since they act as normal hosts for the flea of the dog and cat, which often annoys man; they sometimes harbor the human flea and are frequently heavily infested with the sticktight flea. In cases of house infestation, while it is imperative that the breeding places be treated, attention should be given to dogs and cats. In fact, the destruction of the breeding places and the clearing of the fleas from the hosts should be undertaken simultaneously, as each is essential to the best success of the other. A number of different methods of destroying the insects on animals have been tried, and each has its advocates. The writer has used certain creosote derivations, among them creolin, with excellent results. There are several preparations similar to creolin which would probably be equally effective. It is best to make up a 3 per cent solution of creolin, or one of the similar preparations, in warm water in a tub and place the animal into it; then with a stiff brush to work the solution into the hair. The animal should be kept in the solution 5 or 10 minutes, particular care being taken thoroughly to wet the fleas which crowd to the head of the animal. After the host has been thus treated the creolin water may be drained off and the animal washed with warm water and soap. This washing is not always necessary or advisable in treating dogs, but it is desirable with cats. By this method the burning of the most delicate-skinned animal is avoided. Where a graduated glass measure is not at hand, a 3 per cent solution of the wash may be made by putting in 4 tablespoonfuls of creolin to each gallon of water.

Another treatment, which is reported by Mr. A. A. Girault, of the Bureau of Entomology, to be effective in ridding cats of fleas, is naphthalene. Moth balls were finely pulverized and the powder worked into the fur. The fleas soon began coming out of the hair and on account of their stupefied condition were easily caught and killed. The treatment slightly sickened the cats for two days, but had no serious effect. Insect powder, sometimes called pyrethrum, buhach, or Dalmatian insect powder, may be applied to the fur of animals in the same way. It is not harmful to the host and causes the fleas to come out of the fur in a stupefied condition, when they may be collected on a newspaper and destroyed by burning. It is important that fresh unadulterated pyrethrum be used to secure satisfactory results. The destruction of the chicken flea or sticktight on poultry seems to be rather difficult. Where heavy infestations are present the careful application of kerosene and lard—1 part kerosene to 3 parts of lard—to the masses of fleas gives fairly good results. Care must be taken not to apply too much of the mixture and not to get it on the parts of the fowl where it is not necessary, as it will prove injurious if used too freely.

CONTROL OF HOSTS.

One of the common practices to avoid flea infestation of houses is to keep all dogs and cats out of doors. This is often not desirable, and it also gives an opportunity for the infested animals to start breeding places under the house or in the yard or barn, hence this practice without treating the animals for fleas is objectionable. Not keeping dogs or cats will, of course, largely solve the dog-flea problem, but this is not always feasible. Moreover, the stray animals must also be considered as possibilities in house infestation. From the standpoint of flea control, as well as for the prevention of important diseases, the strict enforcement of dog-control measures and the destruction of all stray cats and dogs is imperative. Dwellings and other buildings should be arranged to prevent cats, dogs, hogs, chickens, and other animals from going beneath them, as the conditions under buildings are often favorable for flea breeding and these locations are exceedingly difficult to keep clean or treat after infestation is started. Numerous instances have come under observation where such conditions were responsible for infested dwellings and heavily infested animals.

Along this same line is the question of separation of hosts. It is bad policy to keep all kinds of animals in close proximity in localities where fleas are numerous. Dogs and cats sleeping around poultry pens are often responsible for keeping chickens constantly stocked with sticktight fleas. Horses kept in buildings where chickens roost

or in barns adjoining chicken coops have been known to become infested with sticktight fleas, and dogs and cats readily infest one another with these and with other fleas. Chickens have been known to become infested with chicken fleas and thus establish an infestation in uninfested yards when allowed to run at large and come in contact with infested premises.

The question of rat control logically should be discussed under this topic, but it has been briefly taken up under "Bubonic plague." Ground-squirrel destruction, aside from its direct economic importance, should also be considered in connection with the relationship between the squirrel fleas, their hosts, and the transmission of plague. The ground squirrels of California are discussed by Dr. C. Hart Merriam in Circular No. 76 of the Bureau of Biological Survey. Much useful information on the control of the California ground squirrel is given, and this is for the most part applicable to ground squirrels in other parts of the country.

DESTRUCTION IN BREEDING PLACES.

Attention has been called (pp. 8–9) to the usual breeding places of different species of fleas. It is evident that destruction of the adult fleas on hosts is almost a hopeless method of controlling the pest if no attention is paid to the breeding places of the immature stages. As has been stated, flea eggs may produce adult fleas from two weeks to many months later. Thus the hosts will continue to become reinfested as fast as the insects upon them are destroyed.

The first step in making war on the breeding places is to determine where the fleas are coming from. Enough has been said in the discussion of life history and breeding habits of fleas to point out the places to be considered. In other than house infestations all unnecessary rubbish and dry animal or vegetable matter should be piled up and burned. In the case of infested chicken houses or sheds the manure should be hauled into an open field, and scattered thinly over the ground. When thus exposed all stages are soon destroyed.

Following this preliminary work, which is essential to the success of the subsequent treatment, the ground, outhouse floors, and other places where the breeding is supposed to occur should be sprayed with kerosene, or, better still, crude petroleum should be sprinkled freely about. To prevent reinfestation or breeding it is essential that all waste, both vegetable and animal matter, be kept scrupulously cleaned up. The most inexpensive and satisfactory preventive measure following the destruction of the main infestation is a liberal use of salt scattered about the breeding places and then thoroughly wet down. In many instances observed in Texas the sticktight flea has been kept out of poultry runs by cleanliness

and semiweekly wettings with water. Along the coast salt water from the Gulf is used extensively for this purpose. The soil must be thoroughly wet, as light sprinklings of the surface will not suffice. The watering is most effective when done in the evening, as drying does not proceed so rapidly then as during the day. Mr. D. L. Van Dine, in treating premises infested with the dog flea in Hawaii, used a dressing for the ground under the houses consisting of 20 pounds of air-slaked lime, 3 pounds of sulphur, and 1 pound of buhach. This mixture was applied after the ground had been thoroughly cleared of all refuse. The outbreak was completely controlled in these cases, but it is difficult to say just what part the above dressing played, as the destruction of the adult fleas was undertaken, as well as other measures.

The breeding of the sticktight flea may be prevented to some extent by the use of metal chicken houses, as is advocated for the fowl tick.[1] These galvanized-iron houses provide less protection for fleas than do frame structures, and the intense heat within them during the daytime practically prohibits flea breeding. The dog house should be cleaned out thoroughly at weekly intervals, and if any flea breeding starts the method of destroying the insects, as outlined in the preceding paragraphs, should be followed. By providing a few gunny sacks or a mat for infested animals to sleep upon, it is possible to concentrate the eggs on these. The eggs may be destroyed then by shaking the cloths over a fire or even out on the bare ground in a place exposed to the sun. This should be done about every second day in order to prevent hatching.

Attention is directed to house infestations, which, by the way, are often supplemented by infestations under the houses or in other out-of-door situations. The occurrence of fleas in dwellings is often connected with the keeping of a cat or dog indoors. If this is the apparent source of infestation, the animal should be treated as previously described and kept out until the indoor work is completed.

If the hosts have been confined largely to one room, this is the one to receive most careful attention. The floor covering should be removed, aired, and beaten, the floor thoroughly swept, and all of the dust obtained should be burned, as it contains many immature fleas. It is best, then, to scrub the floor with strong soapsuds or sprinkle it with gasoline, being careful to avoid having fires about. After sprinkling naphthalene crystals or insect powder over the floor, return the floor covering.

Dr. Henry Skinner, of Philadelphia, found that he could control fleas completely in a house by taking one room at a time, scattering

[1] Bishopp, F. C. The fowl tick. U. S. Dept. Agr., Bur. Ent., Cir. 170, 14 p., 5 figs., 1913.

5 pounds of flake naphthalene over the floor, and closing the room tightly for 24 hours. This remedy was found inexpensive, as the naphthalene could be swept up and transferred to another room.

Dr. Howard has called attention to the method of control used by Miss Adele M. Fielde, who has had extended experience with fleas in China. She states that it is possible to control the fleas there by the use of alum. This substance is added to the whitewash or calcimine used on the walls, paper is dipped in a solution of alum and put under rugs and matting, and powdered alum is sprinkled on carpets or other floor covering and swept in. It does not injure the rugs or matting, but banishes the insects, according to Miss Fielde's statements.

In houses where vacuum cleaners are used at frequent intervals the number of fleas coming from the floors may be reduced. In cases of infested houses a thorough cleaning of the carpets and floors with a vacuum cleaner, provided it is efficient, would largely mitigate the pests.

Fleas in different stages in dwellings or other buildings may be destroyed by fumigation with sulphur fumes or hydrocyanic-acid gas. Either of these fumigants, when properly handled, will destroy the fleas, and has the advantage of killing the rats and mice as well. The use of sulphur[1] is efficient and simple, but has the objection of corroding metal and injuring plants. In fumigating, the infested building should be closed up tightly and the sulphur weighed out at the rate of 4 pounds to each 1,000 cubic feet of space. The sulphur is piled up cone shaped in a pan or kettle, which is placed in a larger pan or tub of water to avoid fire from the heat generated. A depression should be made in the top of the cone of sulphur, a little alcohol poured into it, and a match applied. Each room to be fumigated should have a vessel, and large rooms should have two, one located near each end. It is preferable to do all of the fumigation simultaneously. The rooms or building should be kept closed for from 10 to 12 hours. Although this gas is not nearly so dangerous to man as is hydrocyanic-acid gas, the rooms should be thoroughly aired before entering them. The corrosive action of the gas on metals and its effect on plants should not be overlooked. This may be minimized by fumigating when the atmosphere is dry.

Owing to the poisonous character of the ingredients used and the deadliness of the gas generated, fumigation with hydrocyanic-acid gas should not be undertaken without carefully reading the directions[2] for the operation, and then only by an experienced person.

[1] Marlatt, C. L. Sulphur dioxide as an insecticide. *In* U. S. Dept. Agr., Bur. Ent., Bul. 60, p. 139–146, 1906.

[2] Howard, L. O., and Popenoe, C. H. Hydrocyanic-acid gas against household insects. U. S. Dept. Agr., Bur. Ent., Cir. 163, 8 p., 1912.

Sodium fluorid is a comparatively new insecticide which will probably be useful against fleas. This substance is not expensive and not dangerous to handle. The crystalline powder is applied by dusting it over the carpets or floors and working it into the cracks. For the adult fleas it may be blown about the floor and corners with a dust gun or insufflator. Although this substance has not been tried in this way, it is possible that it can be advantageously utilized in chicken houses, dog kennels, etc., by blowing it about the floors with a powder gun. The fact that sodium fluorid is an excellent remedy against cockroaches further commends its use about houses infested with fleas.

A number of things should be mentioned which may be utilized to some extent in flea-infested regions to prevent the breeding of fleas in dwellings. As far as possible, rugs, or art squares, or other coverings which can be taken up and permit keeping the floors more cleanly, and in case of infestation make treatment easier, should be used. Closely matched floors are beneficial, as there are fewer cracks in which the young fleas may develop. Where cracks are present they may be filled with plaster of Paris or putty. The use of floor oil or of efficient sweeping compounds on floors seems to aid in preventing flea breeding.

TRAPPING FLEAS.

Little dependence for control of fleas can be placed on methods designed actually to capture, repel, or exclude from the host the adult fleas if not supplemented by the other repressive measures just discussed. Nevertheless, under certain conditions, such as in instances where a few adults are produced in a great number of situations, thus making complete stopping of breeding very difficult, or while the other methods of control are being put into effect, trapping, repelling, and isolating are of some value. In localities where plague is prevalent, or even suspected, the importance of keeping even a single flea from biting man is apparent.

Where only a few fleas are present in a dwelling and breeding in the floors is not suspected, the adults may be caught by placing a number of sheets of sticky paper on the floor. In extreme cases, where the persons attempting to rid premises of fleas are liable to injury or serious disease, the practice of wrapping fly paper, sticky side out, around one's legs and walking about is sometimes resorted to. The movement causes the fleas to jump, and if they strike the paper they are held fast. The use of sticky fly paper in this way was probably first tried by Prof. S. H. Gage at Cornell University. One of the university buildings was cleared of fleas by having the janitor, with legs wrapped in fly paper, walk back and forth in the infested rooms. Mr. D. L. Van Dine also made use of this scheme in Hawaii.

In this instance, however, it was used mainly to protect the workmen who were clearing up flea-infested premises.

Lights have been used as traps for the adults in some instances. The results will no doubt vary with the species of flea concerned. A light trap which was used by Mr. E. M. Ehrhorn, formerly of San Francisco, is described by Dr. Howard, as follows:

> Fill a glass three-fourths with water, on top of which pour about an inch of olive oil, then place a night float (a little wick inserted in a cardboard disk or in a cork disk) in the center of the oil. Place the tumbler in the center of a soup plate filled with strong soapsuds. The wick should be lighted at night on retiring, or may be used in any dark room. As the soup-plate soapsuds trap is placed on the floor of the room, it does not interfere with the sleeper, and the fleas which are on the floor are attracted to the light.

A small flea trap which is extensively used in parts of China, and is said to be very beneficial, has recently been described by Dr. E. Hindle. In China two pieces of bamboo are used in constructing the trap. A modified form of this trap, which can easily be constructed by anyone, is illustrated in figure 9.

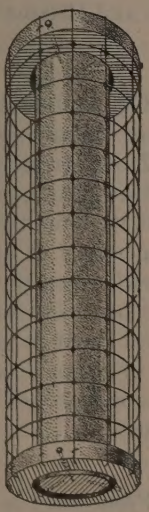

FIG. 9.—Flea trap. The central cylinder is removable and is covered with sticky fly paper. (Original.)

To construct the trap, bore two holes, about an inch and a quarter in diameter, in a board anywhere from one-fourth to 1 inch in thickness. With a keyhole saw or a pocket knife cut out a disk of the board around each of the holes about 2½ inches in diameter. Take a piece of wire netting, with one-fourth or one-half inch square soldered mesh, about 2 feet wide, and tack it around the disks, having one at either end. Cut off the wire, leaving the ends long enough to overlap along the side of the cylinder, and bend the ends in to complete the cylinder. Around a broom handle or other stick about an inch in diameter and equal to the length of the cylinder wrap a piece of sticky fly paper, sticky side out; tack it at each end to the stick and insert the stick into the cylinder. The stick should be fastened in with a nail inserted into it through a hole in the edge of one of the wooden ends. The outer wire cylinder forms a protection for the sticky surface and enables one to move the flea stick around between the bed sheets or to roll it over the flea-infested floor, thus disturbing the fleas, which are caught on the sticky paper. The stick may be easily removed and a new piece of fly paper put on when necessary.

Animals have been used as traps for fleas in experiments conducted by the Indian Plague Commission and others. The Commission

found that guinea pigs left free in rooms picked up considerable numbers of fleas of different species. Men also acted as traps by going about in an infested room, and the fleas thus picked up were caught. No doubt rabbits, cats, or dogs could be utilized in the same way and the fleas destroyed by the methods mentioned under "Destruction of fleas on hosts." This method of picking up fleas is sometimes applicable to certain places in districts where plague exists and it is desirable to capture and destroy the few fleas which might otherwise get upon man.

The use of fresh meat to attract fleas onto fly paper and into traps has been considered to have some merit, but tests made by Drs. Howard and Mitzmain and by others show that it is without value.

REPELLING FLEAS.

The usefulness of repellents is even more limited than that of traps. Many things have been advocated from time to time, or in different sections of the country, for the driving away of fleas. Oil of pennyroyal is probably most widely used for this purpose, and it seems to have considerable virtue as a repellent. This substance may be applied to the shoe tops, hose, and trousers, or placed elsewhere on the body or clothing, and its use on bedding and floors has been advocated by those in flea-infested regions. The pennyroyal plant is used for the same purpose where it grows. Buhach, oil of cedar, eucalyptus oil, or camphor sprinkled between the sheets give a degree of protection to those compelled to sleep in flea-infested places.

ISOLATION FROM FLEAS.

Frequently in many parts of the country outbreaks of fleas are experienced. In such cases extreme measures are necessary for any degree of comfort. Knowing that fleas have very limited powers of jumping in a vertical direction and of crawling on smooth surfaces, it is practicable to exclude them from beds. The higher the bed is from the floor the better, but one may isolate the bed from fleas in most standard-height beds if care be taken to keep the clothing from hanging down. Of course it is essential that no fleas be taken into the bed on the body or the night clothing and that the bedding does not touch the walls or baseboard. It is possible also to isolate a bed or cot or a person sleeping on the floor, if the floor itself is not infested, by placing a band of sticky fly paper or paper covered with a sticky substance 14 inches wide around the bed. In case the legs of a bed are rough, which permit fleas to crawl up them, a band of sticky substance may be painted around the bottoms from 4 to 5 inches above the floor, or, if more convenient, the legs of the bed may be placed in large pans of water.

When the fleas are carriers of disease they are, of course, much more dreaded than when their greatest injury is their bite. Where extreme measures are needed the possibility of a man's protecting himself from fleas while working in infested locations or even while sitting in an infested room by wrapping his legs with fly paper should be borne in mind. A man may get considerable protection from the sticktight flea by wearing khaki or denim trousers and having them tucked into hightop shoes. Leather boots with the tops on the outside of the trousers also keep many fleas from gaining access to the body.

REMEDIES FOR BITES.

As has been stated, fleas in the act of biting inject saliva into the wound, thus producing more or less irritation and itching. Ordinarily no treatment of the bites is necessary; but where they are numerous, especially in the case of susceptible persons, cooling lotions will give relief. Menthol and camphor are beneficial, and carbolated vaseline, carbolic acid in water (a 3 per cent solution), and hydrogen peroxid are each said to relieve the itching and inflammation.

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